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ANALYSIS OF FACTORS THAT INFLUENCE LONGEVITY AND SAFETY OF THE THIN-WALLED CONCRETE CONSTRUCTIONS

ANALIZA CZYNNIKÓW WPŁYWAJĄCYCH NA TRWAŁOŚĆ I BEZPIECZEŃSTWO CIENKOŚCIENNYCH KONSTRUKCJI BETONOWYCH

A b s t r a c t

General data according to the conducted examination of some monolithic and precast steel concrete constructions of tower type, which were built by authors in Ukraine in the period from 2006 to 2011, has been described in this article. Conducted research has shown that unqualified implementation of separate works and factory defects in constructional elements are the basic reason of ruining the buildings and constructions. The materials of the analysis of the consequences from ruining buildings and constructions, and their elements from the defects during implementing building – assembly works, defects from technologic and random impacts are important in the way that from this analysis certain thoughts concerning making basic actions, which are directed on dissolution of different kind of defects to provide reliable operation of buildings and constructions, can be done.

Keywords: cooling tower, pipes, silage, defects, operational capability

S t r e s z c z e n i e

W artykule przedstawiono uogólnione wyniki badań niektórych monolitycznych i prefabrykowanych cienkościennych żelbetowych budowli wykonanych na terenie Ukrainy przez autorów w okresie od 2006 do 2011 roku. Badania wykazały, że głównymi przyczynami zniszczenia budowli są: zła jakość wykonania niektórych rodzajów prac i wady fabryczne elementów konstrukcyjnych. Bardzo ważne są wyniki analizy przyczyn zniszczenia budowli oraz ich elementów na skutek błędów w trakcie wykonania prac budowlanych, wad technologicznych i efektów losowych. W oparciu o tę analizę można przewidzieć kluczowe działania mające na celu wyeliminowanie różnych defektów w celu zapewnia trwałości i niezawodności budynków i budowli.

Słowa kluczowe: chłodnie kominowe, kominy, silosy, wady, trwałość

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1. Introduction

One of the crucial problems of capital construction, which is the key problem in the issues of increasing the effectiveness of labor, its productivity, saving of labor and material resources, is the quality of construction. In this context we shouldn't forget about the influence of the human factor on the quality of construction.

Without profound improvement of construction quality, it is nonsense to implement all other objectives, thus they will strengthen the crisis matters in the sphere of national economy in general and have a ruining loss. If we don't prevent flaw (defects) in the construction, the consequences will be future planned repair and strengthening, changing the construction, accidents and early wear of buildings and constructions.

Most interminable constructions, which are being built 10–15 years, undergo repair and reconstructions even during the implementation work. A lot of them are still being built and used after the reconstructions, while others are forgotten and mothballed projects.

Nowadays, one of the serious objectives is the evaluation of operational capability and safety of holding constructions which are used more than 30 years [1, 2] or are under the conditions of mothballing or not due for a long time to unpredictable atmospheric and climatologic actions.

Critical and profound defects which essentially impact the durability of the constructions or make them functionally unusable can be identified using scientific technical convoy of work implementation concerning reconstruction and finishing building constructional sites. Clients don't always pay appropriate attention to the issues of scientific escort during work implementation of such kind.

Well-timed introduction of scientific convoy facilitates reducing the cost, fasten the work implementation and secure long tern reliable exploitation of building sites.

Scientific convoy of the construction at this stage is in the provision and reconstruction of the building part of basic funds. It is getting actual, at each stage of the creation and operation of the building sites, to take into consideration all the aspects of their functioning. To do this, it is necessary to create a basis of experience in the work performance of such direction and develop a normative and methodological basis for its implementation.

Comparative analysis of the project solutions with the quality of implementation of building and assembly works, give us the ability to identify the influence factors, which are not taken into account during projecting of monolithic and prefabricated iron concrete constructions leading to the declining of their operational capability.

To date, the evaluation and increasing the longevity of monolithic, prefabricated and assembly-monolithic iron concrete constructions, which consist of thin-walled slips: towering constructions (chimneys, silages, spray coolers) built in the period of 60s and 70s, after 36–46 years of exploitation, are crucial and without doubt linked with the evaluation of construction quality.

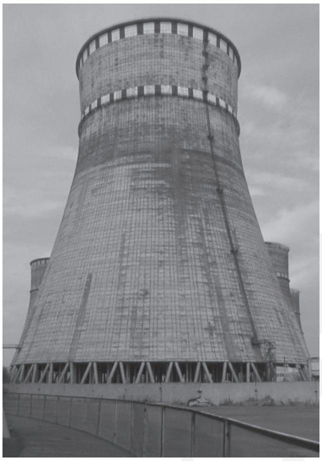
2. Analysis of latest research and publications

The authors of the article have an experience in work implementation, especially concerning examination, evaluation of the technical state of building sites and elaboration of technical solutions regarding the strengthening of the constructions and buildings.

In general, this proves the expediency of wide implementation of scientific convoy during the reconstructions of technically complicated and especially responsible sites.

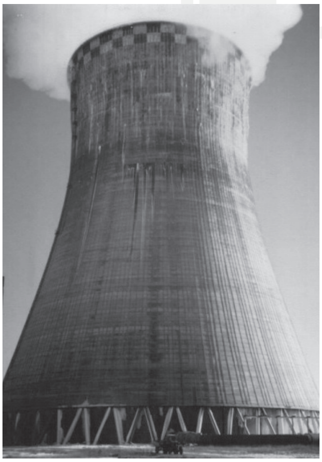
This article has generalized data due to the results of examinations of some thin-walled building sites of tower type (cooling towers, pipes, silages) which are made by the authors within the period from 2006 to 2011, specifically:

– iron concrete monolithic cooling tower station #5 Rivne Power Station [3, 4];
– iron concrete monolithic cooling tower station #1 Kyiv Combined heat and power plant – 6 [5, 6];



Ill. 1. Iron concrete monolithic cooling tower station #5 Rivne Power Station

Ill. 2. Iron concrete monolithic cooling tower station #1 Kyiv Combined heat and Power Plant-6



Ill. 3. Iron concrete monolithic cooling tower station #2 Zuyiv Thermal Power Plant

Ill. 4. Iron concrete prefabricated cooling tower station #4 Darnytsia Combined heat and Power Plant in Kyiv City

Ill. 5. Iron concrete monolithic pipe H = 120 m Kyiv Station #2

Ill. 6. Iron concrete monolithic silages of the building #6 Open Joint Stock Company 'Mykolaiv Cement'

– iron concrete monolithic cooling tower station #2 Zyiv Thermal Power Plant [7, 8];
– iron concrete prefabricated cooling tower station #4 Darnytsia Combined heat and power plant in Kyiv city [9];
– iron concrete monolithic pipe H = 120 m Kyiv station #2 [10];
– iron concrete monolithic silages of the building #6 Open Joint Stock Company 'Mykolaiv cement' in Lviv region [11].

3. Analysis of factors that influence x longevity and safety

3.1. Iron concrete cooling towers

Building constructions of cooling towers of tower type are being used in exclusively pressed mode (alternating moistening and drying, freezing and melting, action of aggressive agents of counter waters and gases in the air) which causes their quick destruction.

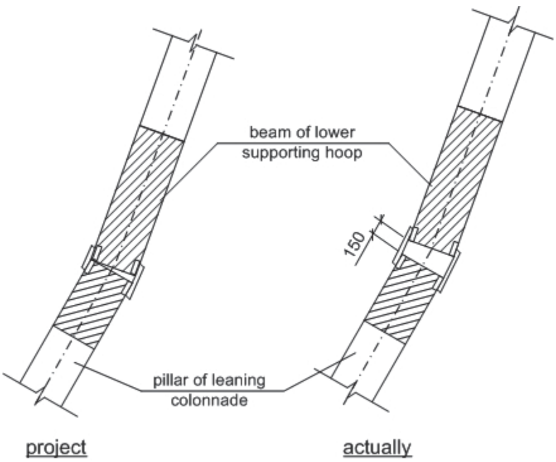
Having investigated the actual state of iron concrete construction of some cooling towers in the Ukraine regarding their durability at the simultaneous impacts of all the above mentioned factors, the authors have found the following facts.

Actual class of concrete pillars (∅900 mm) leaning colonnade of spray cooling towers of Rivne Power Station vary from B_f32.5 to B_f55 (coefficient of variation U_f = 3.25÷14.48%) within the project class B30, which affirms good monitoring of quality of their manufacturing. However, during instrumental research of cracking, the lengthwise shrink and cross-cut cracks in each pillar (Ill. 7) in depth immersion h_{crc} mainly up to 60 mm have been indentified, which result in steel reinforcement corrosion.

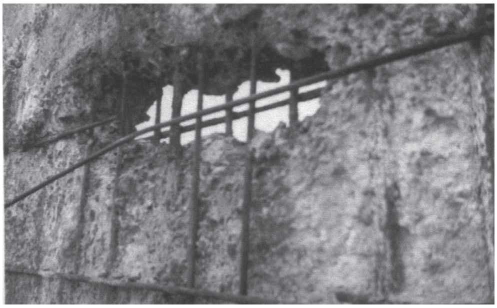
Actual class of concrete pillars (400 × 500 mm) leaning colonnade of cooling towers of Kyiv combined heat and power plant 6 vary within B_f15 to B_f35 (coefficient of variation U_f = 8.48÷31.62%) the project class B32.5, which signifies lack of quality for its manufacture. Changeability of firmness characteristics of concrete pillars leads to redistribution at the lower cover contour of spray cooling towers and at the pillars of leaning colonnade (Ill. 8): 32÷36 mm for working steel reinforcement (according to the project 40 mm) and 17÷32 mm for transversal steel reinforcement (according to the project 30 mm). Besides, it was identified that during the assembly of beams of the lower supporting hoop on the pillars of leaning colonnade, a major constructional error has been made regarding the fact that beams were installed on the pillars 'dry' and 150 mm higher x than the farther monolithing of the knot (Ill. 9). This error was the reason for cracking in the cover of the spray cooling tower.

Ill. 7. The lengthwise and cross-cut cracks in pillars of leaning colonnade of cooling tower station #5 of Rivne Power Station

Ill. 8. Insufficient thickness of protective concrete layer and corrosion of transversal reinforcement in the pillar of leaning colonnade of cooling tower station #1 Kyiv Combined heat and Power Plant 6



Ill. 9. Knot of pressing the pillars of leaning colonnade with iron concrete beams of lower supporting hoop of cover of cooling tower station #1 Kyiv Combined heat and Power Plant 6

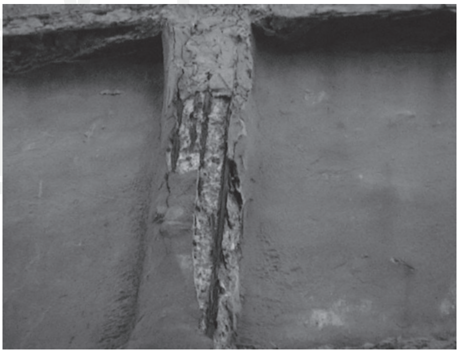


Ill. 10. Defective tier of concreting of cooling tower #2 at Zuyiv Thermal Power Plant (difference +122 m). Deviation of steps of working reinforcement. Absence of linking reinforcement in the net

According to the conducted research [7, 8] of the monolithic iron concrete cover of cooling tower #2 Zuyiv Thermal Power Plant, decent changeability of firmness characteristics of concrete has been approved regarding tiers of concreting. After identifying the most defective areas, the deviation from the project and the steps of working steel reinforcement has been determined, as well as the connection absence of reinforcement bars in the net (Ill. 10).

Actual class of concrete prefabricated iron concrete keyed slabs of the cover of cooling tower #4 of Darnytsia Combined heat and power plant varies between B_f30 to B_f50 (coefficient of variation U_f = 5,56÷20,87%) with the project class B25. Even though the actual class of concrete is larger than the designed one, changeability of coefficients of variation tell us about the lack of quality of its manufacturing. Furthermore, disparity of thickness of protective layers of concrete has been recorded: 0÷14 mm (Ill. 11) for steel reinforcement in the shelves of keyed slabs (according the project 18.5 mm) and 10÷60 mm (Ill. 12) for working steel reinforcement in keys of slabs (under the project 30 mm).

Ill. 11. Steel reinforcement corrosion and destruction of concrete of upper belt of firmness of the cooling tower #4 at Darnytsia Combined heat and Power Plant, protective layer of concrete is lower than designed



Ill. 12. Steel reinforcement corrosion and destruction of concrete of vertical ribs of prefabricated slabs of cover of cooling tower #4 at Darnytsia Combined heat and Power Plant, protective layer of concrete is lower than designed

Besides, it was observed that complicated details of adjacent slabs are linked with metal cover straps and the maximum designed thickness of the protective layer of concrete of laps is only 7 mm, which is not sufficient for the protection of the corrosion processes. Moreover, this protective layer is made of ordinary gunite which has not enough adherences to the material.

3.2. Iron concrete haze pipes – complicated long high-altitude engineering constructions

Quite often the defects of haze monolithic iron concrete pipes are mentioned because of low quality materials and constructions. It is necessary to say that defects which are linked with low quality protection from atmospheric and technological influences are stipulated by an attitude of neglect to the manufacturing of details and the constructions themselves, inefficient performance of the departments of surveillance of ‘the construction and exploitation of the buildings.

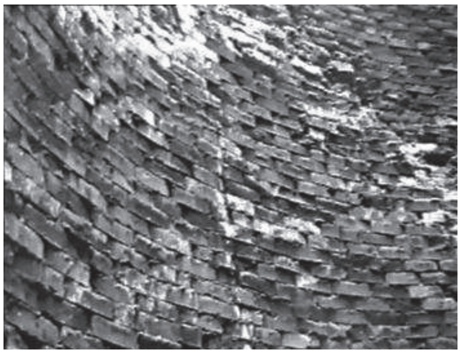
Having investigated the actual state of construction of iron concrete haze pipe H = 120 mof Kyiv station #2 [10], the authors have found the following things.

Actual class of concrete monolithic stem of pipe at different levels of height varies within B_f17.5 to B_f22.5 (coefficient of variation U_f = 17,7÷29,2%) under the designed class B25. Insufficient firmness of concrete and decent changeability are due to insufficient monitoring of firmness characteristics of concrete and technologies of its stacking during the installation of stem pipes. Besides, during the process of examination, the spots of insufficiently compressed concrete have been determined, as well as sulfate corrosion of concrete and deflation (Ill. 13, 14).

Ill. 13. Insufficiently compressed concrete at the joint of tier of concreting

Ill. 14. Sulfate corrosion of concrete, filtration of moisture at the joint of concreting

To protect supporting stems of haze pipes from the impact of high temperatures and acids, protective fettlings are used which can be made of bricks, steel, polymer concrete or others. If the cracks appear in fettlings, burnout or other defects, destruction of the supporting stem can be doubly accelerated. During the examination of inner fettling of monolithic iron concrete pipes, the destruction of the brick wall of fettling with “through” penetrating? cracks has been identified (Ill. 15).

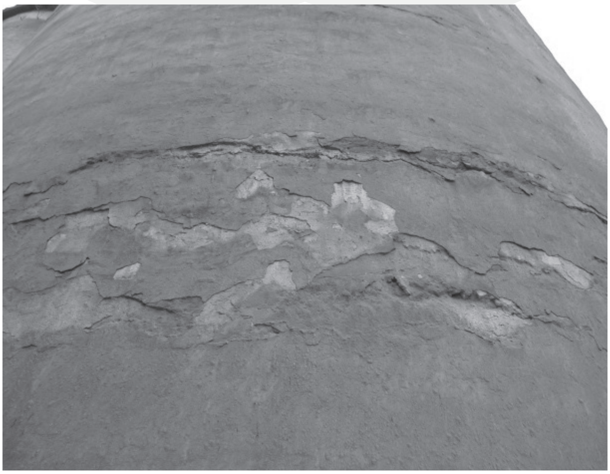


Ill. 15. Destruction of brick wall of fettling

3.3. Iron concrete monolithic silages – reservoirs to save friable materials

Conducted instrumental research [11] of monolithic iron concrete constructions of eight silages of building #6 at the factory Open Joint Stock Company 'Mykolayv Cement', after 42 year exploitation, has shown the following results.

Actual class of concrete of monolithic iron concrete constructions varies within B_f10 to $B_f22{,}5$ (coefficient of variation $U_f = 9 \div 35{,}8\%$) when designed class is B15. Although the actual class of concrete in the majority of constructions satisfies designed significance, changeability of coefficients of variation indicates the insufficient quality of its manufacturing. In addition, according the investigation of the walls of silages, the disparity of thickness of the protective layer of concrete has been recorded – $10 \div 40$ mm (due to the project 20 mm). Under the least thick protective layers, exfoliation is occurring and uncovering steel reinforcement as well (Ill. 16). Besides, the changeability of the steps of vertical and circular steel reinforcement of the walls of silages (up to 52.3% for vertical and up to 80% for circular steel reinforcement) has been noticed. All these point to low quality of control in all technological cycles of construction manufacturing.



Ill. 16. Scaling of protective layer of concrete with stripping and corrosion of steel reinforcement on the surface of silage walls

Conducted research has shown that inferior performance of certain types of work and factory defects in constructional elements are the main issues of destruction of buildings and constructions. Losses from defects in x construction are happening because of the lack of appropriate monitoring over the following:

– using sub-quality construction materials supplied to the construction site, which are suitable to the requirement of the project,
– adherence to the allowances and aberrations from the standardized and designed solutions: lengths of elements and sizes of their diametrical cross cuts, thickness of the protective layer, pitches of steel reinforcement and other geometrical parameters,

– actual quality of implied output materials to produce concrete (cement, fillers, water) at all stages of technological process to ensure the necessary design firmness and homogeneity of concrete,
– work performance (installing concrete mixtures and their maintenance, quality of welded and other connections etc.).

4. Conclusions

The information taken from the analysis of the consequences of destruction of buildings and constructions and their elements, from the defects during the implementation of building assembly works and flaws from technological and random impacts are important in a way that out of this analysis some thoughts, regarding the dissolution of different kind of defects to provide reliable operation of buildings and constructions, can be made.

Under the conditions when almost all governmental establishments which are responsible for quality assurance have been terminated in the Ukraine, the situation regarding the quality of construction is getting considerably worse and worse, which is not a good position anyway. The most dangerous tendency is the abrupt redundancy of the amount of building laboratories, geodesic and metrological services, and quality assurance engineers.

Building manufacture and its monitoring should not counteract each other, since more precise controlling doesn't guarantee the absence of defects, but the quality assurance of the building operation implementation can give the possibility to prevent, identify and eliminate the reasons which cause flaws, and the members of building manufacturing have to realize this by themselves.

The issues of construction quality have to be solved on a scientific basis. Quality control pertains not only to building materials, construction and other works, but also to all stages of building processes, particularly the technology of building manufacture and personnel qualification. The management activity as a whole, has to be directed to receive building precuts of certain quality and on time defect prevention, the further correction of which, would be quite an expensive issue.

In the case of the creation of mutual enterprises with foreign partners x in the country, these companies will face a new processes which our national building firms have never experienced so far. Thus, the functions of technical surveillance have become the functions of the representatives of foreign firms and in the manufacturing activity the issues of reaching high quality, which has been minor until recently, must be solved.This reality, forced to gain more profound knowledge of methods of how to assure high quality of building work performance according to the requirements of Building norms and rules, governmental building norms, governmental standards of the Ukraine, state standards, departmental norms, norms of foreign partners and other regulatory documents. The foreign partner doesn't take into consideration our difficulties and inability to find an agreement. In case we can't do something or refuse to implement any kind of work, another worker is hired and the building company loses x part of the desirable revenue.

The necessity to guarantee the customer and consumer appropriate quality and refund in case of inflicted loss can lead to the need to insure the quality which is analogical to the one which is stipulated by law, and includes the building expenses in the cost of insurance fees.

The conditions which guarantee quality must become an attestation of the contracting agency where its technical equipment must be taken into consideration as well as staffing levels of the appropriate type and qualification, availability of control-measuring equipment, devices, tools and presence of structural subdivisions of the organization, which are responsible for regulatory compliance and maintenance of governmental standards.

It is possible to introduce some actions, which are implemented in other foreign countries, where the institutes of quality and service of state building surveillance that provide services to municipal authorities are present, but in all these cases a new and more profound approach to protect the interests of government and customers of building products must be realized.

In the situation where the possibility of global modernization of economy is absent, the function of safe exploitation of old constructions is getting more important.

One of the promising directions to enhance the reliability of buildings and constructions from accidents, is the need of constant monitoring of their technical state. In order to prolong the periods of safe utilization of buildings and constructions, it is necessary to ban their further exploitation when they reach their deadline of normative exploitation. To allow continuation of the period of their exploitation, it is necessary to evaluate the residual resource of these buildings and constructions according to the conclusions of expert examination, using new efficient and technological solutions to extend their capability and appointment to the next term of their exploitation.

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